AN INTERNATIONAL STRATEGIC PLAN FOR SPACE LIFE SCIENCES

June 1995

I. PREFACE

A. Purpose of the Plan

This international strategic plan, developed by representatives of six space agencies, provides the multiagency framework for the development of the field of space life sciences from the present into the 21st Century. This plan: presents the interests and goals of each participating space agency in the same format in order to identify the mutual interests and programmatic compatibilities of the various agencies; serves to enhance communication and unity among and between the participating space life sciences communities around the world; and enables a more complete coordination of the international development and utilization of space flight and special ground research facilities.

This plan focuses on ways to achieve the following two primary goals that form the foundation of all international activity in the space life sciences:

Goal 1: Strengthen Space Research

To strengthen space research by using an international framework to exploit the space environment for the optimal production of new scientific information in the space life sciences;

and

Goal 2: Enhance Knowledge and Information Exchange

To enhance the capability to coordinate and facilitate the international exchange of scientific and technological information and knowledge in order to:

a. Improve the scientific foundation of our understanding of the processes related to life, health, and disease;

b. Strengthen the scientific underpinning of programs to assure safe and productive human space flight; and

c. Contribute meaningfully to the development of various applications of space technologies and biotechnologies to the solutions of the scientific and medical problems on Earth.

Thus, this plan contains a set of objectives that achieve each of the above goals. These objectives are consistent with the current plans of each of the participating agencies. Through this plan, a framework is defined that facilitates the identification of opportunities for coordination and cooperation utilizing the full range of space carriers, platforms, ground-based facilities, and scientific expertise for the ultimate good of the international space life sciences community.

B. International Participation in the Planning Process

The space agencies involved in the development and implementation of this Strategic Plan are the United States National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and the space agencies of Canada (Canadian Space Agency, CSA), France (Centre National d'Études Spatiales, CNES), Germany (Deutsche Agentur für Raumfahrtangelegenheiten, DARA), and Japan (National Space Development Agency of Japan, NASDA). The individual space agencies have contributed to this plan and, while still maintaining individual agency autonomy for their own programmatic decisions, have committed to support the unification of a world space life sciences community for the benefit of scientific progress in our field.

C. Definition of Space Life Sciences

Life evolved on Earth under a unique set of conditions. As far as we know, all living organisms have survived and flourished in the extraordinarily narrow and stable range of physical parameters characteristic of the environment on the Earth÷s surface. Such an environment includes a narrow range of temperatures and pressures, daily and seasonal cycles, and partial protection from space radiation by the Earth's atmosphere and magnetic field. In addition, the environment in which living organisms evolve and thrive on Earth includes the clear presence of a strong spatial orientation cue provided by the direction and magnitude of Earth's gravity.

In space, even a short distance up from the Earth's surface, most of these conditions are not present. Environmental variables, such as temperature, pressure, and lighting cycles in a spacecraft or space habitat require active control to ensure viability of living systems. In a spacecraft, the forces of gravity are effectively nullified by the balance of physical forces maintaining the spacecraft's orbit. Thus, the entire spacecraft becomes a laboratory model of Earth with a small but important set of largely controllable variables. Among these variables is the effective 'gravitational' force experienced by inhabitants of the spacecraft.

Until humans ventured into space there was no good way to determine just how gravity influences the normal functioning of organisms on Earth. The effect of gravitational-like forces on the development, growth, and functioning of living systems can be revealed only by conducting systematic research over the entire gravitational range, from the microgravity of space to the hypergravity provided by centrifuge facilities on the ground and, perhaps one day, by large centrifuges in space. Through such research, we can hope to uncover a few more of the secrets of life on Earth.

Space life sciences is that area of life sciences research and technology that is concerned with *interactions* between *living systems* and a*ny* of the att*ributes o*f the spa*ce environment. T*he term "living systems" includes **all** of the **fundamental bioprocesses** of which they are comprised. The space life sciences include, but are not limited to, the following activities:

- the understanding of fundamental life processes by investigating how living systems respond and adapt to the space environment;
- the use of the capability afforded by space flight to understand the impact of biology on the Earth's ecological balance;

- the understanding of the origin, evolution, and distribution of life in the universe;
- the provision of operational medical support to all space missions involving humans and the development of protective and therapeutic means to cope with the hazards of space exploration; and
- the development of the scientific and technical foundation for expanding human presence beyond Earth orbit.

Such research activities are supportive of the three primary thrusts of the space life sciences: to develop an expanded understanding of living systems and ecology in the universe, to provide the scientific foundation and technological support systems to enable safe and productive human space activity, and to use the knowledge acquired in the pursuit of space life sciences to improve the quality of life on Earth.

Primary Thrusts of Space Life Sciences

A. To develop an expanded understanding of living systems and ecology in the universe

B. To provide the scientific foundation and technological support systems to enable safe and productive human space activity

C. To use the knowledge acquired in the pursuit of space life sciences to improve the quality of life on Earth

II. THE SPACE LIFE SCIENCES VISION

A. Introduction

One of the primary attributes of the space environment is microgravity. Microgravity affects organisms both directly at the level of the cell and as a whole at the level of the organism, influencing various processes essential to maintain life and to control growth, development, and orientation in plants, animals, and humans. For example, our bone and muscle systems evolved in response to gravity-induced mechanical stresses; under weightlessness, bones and muscles lose mass and minerals are depleted, resulting in the increased risk of fractures. Furthermore, perception of environmental cues and physiological systems interact to induce space motion sickness in space and balance disorders on return to a gravitational environment. Another important feature of the space environment is radiation, which can damage cells that are necessary to the proper functioning of essential organs and tissues, and may initiate and promote mutations and carcinogenesis.

The microgravity of space provides the only way we can escape Earth's gravity for a long enough period to study the role that gravity has played in the evolution and function of organisms.

Microgravity has become a new investigative tool that allows us to address questions of fundamental biological importance. This research involves determining the effects of gravity, from microgravity to hypergravity, on life forms from single cells to whole organisms, including the human body. Fundamental questions in gravitational biology research include: how living organisms sense gravity; the role of gravity in development and other physiological processes; the required levels of exposure to gravity for effective biological function; and the influence of gravity on life's evolution.

In addition, space flight affords a new way to investigate the origin and nature of circadian rhythms because of the separation from Earth's periodic cycles. The controlled environment of a spacecraft allows investigation into the minimum quantity and variety of plants, people, and other organisms required for a self-sufficient and robust environment. The different magnetic fields and reduced convection in space flight afford unique opportunities to probe biological mechanisms in new ways. Space radiation studies and supporting ground research also constitute a useful way to acquire insight into fundamental biological processes; we can gain knowledge of the structure and function of genes, cells, and tissues by studying the development, including repair, of alterations resulting from exposure to radiation.

Human space flight and the conduct of research in space require the maintenance of crew health and performance over long periods in flight, during extravehicular activity (EVA), on planetary surfaces, and upon return to the 1-g environment of Earth. Research and technology development focus on: reliable, self-sufficient life support systems; dependable engineering systems that enable humans to live and work effectively in space; and efficacious countermeasures based on understanding the underlying mechanisms of space flight-induced changes. An understanding of developmental biology is necessary for the design of self-sufficient life support systems needed for long-duration space travel. Basic knowledge gained from psychology and sociology related to long-term isolation and confinement and the interaction between humans and machines must be applied to the structuring of human activities in flight. Exposure to ionizing radiation must be predicted and the risks associated with radiation from solar disturbances and galactic cosmic rays must be controlled.

During the last 10 years, significant scientific progress has taken place in all of these areas of space life sciences because of international cooperation. International space missions have utilized the U.S. Shuttle/Spacelab laboratory in space (SL-1, D-1, SLS-1, IML-1, SL-J, D-2, SLS-2, IML-2) and the Russian (Soviet) systems, Biocosmos and Mir. Such cooperation has been fostered by the development of strong working relationships among all of the major space-faring nations.

B. The Vision for the Next 10 Years

Over the next five to ten years we will advance our understanding of the influence of gravity on living systems. During this time the benefits of the space flight environment as a research tool for life sciences will be well documented, widely acknowledged, and generally accepted by the life sciences community at large. Research in microgravity will lead to new discoveries by using gravity to probe and challenge fundamental biological principles.

By the end of the century, as a result of coordinated ground- and flight-based research, we will achieve great strides toward understanding the mechanisms underlying physiological adaptation to space flight and developing ways to prevent or protect crews from the undesirable effects of extended exposure to the environment of space. We will have a full understanding of the toxicological and microbial hazards within and outside spacecraft and will have developed effective monitoring and preventive measures to ensure the safety and productivity of crew members during long-duration exposure to the space environment. We also will have established the probabilities (in excess of natural incidence) of deleterious health effects resulting from exposure to the space radiation environment, including carcinogenic and mutagenic effects. The resulting new knowledge and technology will be applied to the alleviation of disease and other health problems on Earth.

We will develop technologies and procedures necessary for comprehensive life support systems leading to a closed, regenerative life support system early in the next century. Improvements in waste management systems, sensors, bioregeneration, and air and water reclamation, coupled with active thermal control, will make such a closed system possible. Space human factors research will address high-risk areas in crew performance and will define requirements and develop systems to support mission work analysis, workload assessment, scheduling, and communication interfaces. Among other applications, this work will improve crew selection and training, habitability, human-machine systems, and automation interfaces.

The scientific community will be enlarged significantly as they become aware of the opportunities and benefits afforded by space research. The scientific results from space missions will become easily accessible by that community. New management approaches will be developed to support wider community participation in space flight research.

C. New Challenges for the 21st Century

The 21st Century will usher in a stable era of research in space with a healthy and dynamic community supported by the continuous provision of research opportunities, regular access to space laboratories, and routine scientific operations in space. Preparing for such an era will challenge the infrastructure of each of the various space agencies involved in supporting space life sciences, because success in making the most of the opportunities that present themselves will almost certainly require an unprecedented level and quality of international cooperation among agencies that have traditionally exercised almost complete management autonomy in the pursuit of their individual goals and objectives.

III. INTERNATIONAL PERSPECTIVES

A. Benefits of an International Strategic Plan

An international strategic plan is beneficial to all participants because the resources of the individual agencies and nations are insufficient to carry out the vigorous research program appropriate in the space life sciences. Pooling of resources and talent will strengthen everyone. Sound planning by the various space agencies will promote and increase the effectiveness of interactions among scientists around the world.

B. Brief History of International Cooperation

Table 1 summarizes the history of the development of bilateral working groups among the agency members of the Working Group.

TABLE 1

BILATERAL WORKING GROUPS IN SPACE LIFE SCIENCES

(Year of Formation)

AGENCY	CNES	CSA	DARA	ESA	NASA	NASDA
CNES	-	1990*	1986***	**	1985	1992*
CSA	1990*	-	1994*	1993*	1988	1993*
DARA	1986***	1994*	-	**	1985	1988***
ESA	**	1993*	**	-	1986	1989***
NASA	1985	1988	1985	1986	-	1986***
NASDA	1992*	1993*	1988***	1989***	1986***	-

*** Indicates meetings without formation of joint working group**

****ESA Member State**

***** Interagency Working Group**

The remainder of this section contains a chronological list, from 1980 to 1994, of the international space life sciences activities of the various members of the Working Group.

Chronology of International Activities in the Space Life Sciences Since 1980

1980

Preparations under way for the first Spacelab mission on the U.S. space shuttle

1982

Flight of French cosmonaut on USSR Soyuz T-6 mission

1983

First Spacelab Mission (SL-1) with one ESA astronaut

USSR flight of Cosmos biosatellite 1514 with international payload

1984

Flight of Canadian astronaut on shuttle mission 41-G

1985

Initiation of cooperation between German (DFVLR) and Russian (Institute for Biomedical Problems, IBMP) scientists

Initiation of Space Life Sciences Working Group between Germany and NASA

Participation of French astronaut in shuttle mission 51G

Shuttle flight of first German Spacelab mission (D-1) with 1 ESA and 2 German astronauts

USSR flight of Cosmos biosatellite 1667 with international payload

1986

Initiation of working group (including life sciences) between Germany and CNES

1987

Initiation of cooperation between Germany and China (Chinese Institute of Space Medico Engineering and Chinese Academy of Sciences)

Initiation of ground-based scientific cooperation between CNES and NASA using bedrest

USSR flight of Cosmos biosatellite 1887 with international payload

1988

Collaborative projects initiated between Canada and USSR

Space Life Sciences Working Group initiated between Germany and France

Initiation of CNES-NASA Rhesus Research Project

Flight of French cosmonaut on USSR Mir mission

1989

First Life Sciences Working Group Meeting between CSA and NASA

Establishment of the German Space Agency, DARA

USSR flight of Cosmos biosatellite 2044 with international payload

1990

First Joint Working Group Meeting between CSA and USSR

Bilateral discussions initiated between CSA and CNES

Initiation of DARA cooperation with USSR, and later certain members of the Commonwealth of Independent States, especially Russia and Kazakhstan

Collaborative projects and scientist exchange initiated between Canada and Japan

1991

Shuttle flight of first Spacelab mission dedicated to Life Sciences (SLS-1)

1992

German implementation of former German Democratic Republic space projects from the Intercosmos program into the agreement between the BMFT and the Russian Academy of Sciences

Shuttle flight of First International Microgravity Laboratory Spacelab Mission (IML-1) with one ESA astronaut and one Canadian astronaut

Participation of one ESA and one Italian astronaut in shuttle mission STS-46

Shuttle flight of Spacelab J Mission with major Japanese payload and Japanese astronaut

Flight of German cosmonaut on Mir station

Flight of French cosmonaut on Mir station

1993

Formal bilateral discussions initiated between Canada and Japan

Discussions initiated between Canada and Germany

Shuttle flight of second Spacelab mission dedicated to Life Sciences (SLS-2)

Shuttle flight of second German Spacelab mission (D-2) with two German astronauts

Russian flight of Cosmos biosatellite 2229 with international payload

Initiation of cooperation between CNES and CPK (Russian space medical group) on pre- and postflight cosmonaut studies

Flight of French cosmonaut on Mir station

1994

Shuttle flight of Second International Microgravity Laboratory Spacelab Mission (IML-2) with one Japanese astronaut

Development of common approach to research in cardiovascular physiology between CNES and DARA/DLR

Flight of ESA astronaut on Mir station (EUROMIR '94), largely dedicated to research in human physiology

Trilateral agreement between CNES, DARA, and CPU Moscow on pre- and postflight cosmonaut studies

IV. A STRATEGY FOR SPACE LIFE SCIENCES

A. Guiding Principles for the International Strategy

A number of fundamental principles form a common ground of understanding among the international partners who developed this plan. These principles cut across all of the thematic elements of the plan and the understanding they engender provides a unified conceptual basis for the plan. This basis underlies the foundation for the implementation strategies to be discussed later.

These guiding principles are defined in the box below and have been adopted by all of the agencies participating in this strategic plan.

Guiding Principles

Underlying the International Strategic Plan

- **Promote the highest quality** scientific investigation with the strongest scientific return possible, consistent with the particular constraints defined by a research opportunity;
- In international cooperative activities, **preserve the autonomy** of each of the participating space agencies;
- **Optimize the utilization** of scarce resources by avoiding unnecessary duplication of equipment, by sharing equipment and flight opportunities, and by cooperating with all partners whenever possible; and
- Recognize that **access to space** is a precious resource and that it should be **increased** whenever feasible and **shared** among international partners.

B. International Goals

A major function of this strategic plan is to promote an understanding of the rationale for and importance of appropriate international cooperation in the space life sciences. The agencies participating in the development of this plan have reached agreement that the two primary goals defined here should form the foundation of **all** international activity in the space life sciences. These two goals relate to the **conduct of research in space** and to the **exchange of knowledge and information** within the international scientific community.

Goal 1: Strengthen Space Research
To strengthen space research by using an international framework to exploit the space environment for the optimal production of new scientific information in the space life sciences.

and

Goal 2: Enhance Knowledge and Information Exchange
To enhance the capability to coordinate and facilitate the international exchange of scientific and technological information and knowledge in order to: a. Improve the scientific foundation of our understanding of the processes related to life, health, and disease; b. Strengthen the scientific underpinning of programs to assure safe and productive human space flight; and c. Contribute meaningfully to the development of various applications of space technologies and biotechnologies to the solutions of the scientific and medical problems on Earth.

These goals transcend the specific scientific programs conducted by any of the individual space agencies and together span all of the current and potential activities in the space life sciences. The first is concerned with all aspects of the actual scientific studies in the space life sciences while the second is focused on the distribution and use of both the scientific results and the advanced technology resulting from these space studies.

C. Strategy

This plan presents a multicomponent, thematically based strategy to achieve each of the above goals. The thematic areas upon which the plan is based consist of a logical collection of the major activities normally required in the management of any internationally based space research activity. These themes taken together represent the sum total of nearly all of the activities undertaken by any space agency to enable international space life sciences research. The strategy used to achieve a goal is presented as the logical sum of the strategies used to achieve a defined set of objectives within each of the thematic areas.

In what follows, the thematic areas will be defined in a way that is independent of the goals to be achieved. Then, a set of objectives will be developed that enable each goal defined above to be achieved. Finally, a strategy will be presented to achieve the necessary objectives; this strategy is the international strategic plan.

1. Thematic Areas

The thematic areas defined in this section represent one logical way of representing the normal set of space agency activities required in the overall management of space research. Such a representation is not unique; the one chosen here is based on convenience only. The thematic areas are listed in the box below; a detailed definition of each thematic area is presented in Appendix E.

The themes themselves fall into five separate groups. The first, consisting only of the **management and policy** area, relates to setting the stage for cooperation through the issuance of specific space agency management directives and policy issues that relate to international cooperation. The second group includes **investigator community development**, **discipline review and planning,** and **science recruitment, review, and selection**. This group relates directly to the development of the strongest possible scientific participation in the research program of the space life sciences. The third group consists of only one theme, **flight and ground facility development and sharing**, that focuses on ways to overcome the resource limitations of any single space agency in providing expensive flight and ground facilities for use by the international scientific community. The fourth group, consisting of **data archiving, distribution, and utilization**, is concerned with making previously collected flight data available to the scientific community and with supporting the utilization of that data to conduct sound retrospective studies. The fifth group, containing both **educational activities** and **Earth benefits**, concerns the transfer of the benefits of space research to the general public, the ultimate supporter of space research.

GENERAL THEMES

WITHIN SPACE LIFE SCIENCES

- Management and Policy
- Investigator Community Development
- Discipline Review And Planning
- Science Recruitment, Review, And Selection
- Flight And Ground Facility Development And Sharing
- Data Archiving, Distribution, And Utilization
- Educational Activities
- Earth Benefits

2. Strategy to Strengthen Space Research (Goal 1)

Achieving the first goal, related to space research, involves achieving specific objectives related to the following themes: management and policy; discipline review and planning; flight and ground facility development and sharing; and science recruitment, review, and selection.

In the **Management and Policy** area, the various space agencies should continue to provide resources that support regular meetings of the Working Group so that this Strategic Plan can be maintained and implemented. At these meetings, each agency should continue to present the status of their life sciences activities fully to the other members. The members of the Working Group should promote mechanisms for internationalizing space research by alerting management groups in different space agencies to potential international space research opportunities and by encouraging individual agencies to make such opportunities available to the international scientific community.

In the **Discipline Review and Planning** area, the various space agencies should define scientific research areas in the space life sciences using common terms. This standardization will enhance communication among agency personnel and will allow the scientific community to more clearly advocate various programs in a uniform way. Then, the agencies should carry out an international review of the status of space research in each area, define the critical questions and determine the relative importance of these questions. They should accomplish this by developing a plan to hold a series of regular meetings of scientific experts to carry out this objective. These meetings should result in a published report on the status of knowledge and the critical questions in each research area.

In the **Science Recruitment, Review, and Selection** area, the agencies should strive to make flight opportunities available to the international scientific community on a competitive basis. Whenever feasible, this should be accomplished by utilizing announcements of flight opportunities that are open to any member of the scientific community. These announcements should be distributed widely within the scientific community. The various agencies should standardize, to the greatest extent possible, the process used for the evaluation and selection of space flight investigations. This should be accomplished by agreeing on the definition of a common core set of evaluation and selection criteria to be used by all agencies to select flight investigations.

In the **Flight and Ground Facility Development and Sharing** area, the agencies should strive to optimize the use of existing space hardware and ground facilities and promote the sharing of this hardware. This should be done by preparing a catalog of the existing space hardware and ground facilities applicable to all scientific research areas and by making such hardware available through bilateral negotiations, as needed. The space agencies should coordinate the planning for the development of new space hardware and ground facilities by exchanging information on the planning for new hardware and facilities and by coordinating the developments as appropriate.

3. Strategy to Enhance Knowledge and Information Exchange (Goal 2)

Achieving the second goal, related to knowledge and information exchange, involves achieving specific objectives related to the following themes:

management and policy; data archiving, distribution, and utilization; investigator community development; educational activities; and Earth benefits.

In the **Management and Policy** area, the space agencies should act to assure the international exchange of scientific information to optimize the yield from space life sciences research by periodically encouraging the development of management policies of the different agencies to maintain their consistency with achieving this objective.

In the area of **Investigator Community Development**, the agencies should devote resources to informing the scientific community at large about the scientific results obtained from space studies in life sciences. To accomplish this, the agencies should: hold space-related scientific sessions at regular meetings of the major scientific societies to inform the community about space life sciences; coordinate the development of scientific reviews of the different space life sciences research areas; and encourage the development of stronger partnerships between space agencies and traditional science funding agencies within each country or region. In addition, this Working Group should develop an annual report of international activity and circulate this widely.

In the **Data Archiving, Distribution, and Utilization** area, the individual agencies should promote the archiving of space flight data as a means of preserving data sets that are difficult to obtain. They should exchange information on the status of data archiving on a regular basis at working group meetings and publicize the availability of such data to the international scientific community. In addition, the agencies should provide a simple means for the scientific community to have access to space flight data and results by developing a uniform approach to data and bibliographic archiving that minimizes the difficulty associated with obtaining data and results.

In the area of **Educational Activities**, the members of the Working Group should encourage the international exchange of graduate and postgraduate students in the space life sciences by preparing a directory of laboratories in various countries that train graduate and postgraduate students in the space life sciences and by making this list available to students throughout the world. In addition, they should encourage the development of educational material and distribute a list of this material to all agencies.

In the **Earth Benefits** area, the Working Group should develop an international report on the Earth benefits of space life sciences research. In addition, each member of the Working Group should intensify the dialogue between the space life sciences community and the non-space life sciences community regarding the real and potential Earth benefits of space research.

V. CONCLUSION

A. Summary of Key Points

The material within the next two boxes summarizes the key features of the Strategic Plan.

Goal 1: Strengthen Space Research

STRATEGY

- Maintain Strategic Plan
- Internationalize Space Research Opportunities and Make Flight Opportunities Available to International Community on Competitive Basis
- Standardize Definitions of Research Areas
- Review International Research Progress and Assess Critical Questions in Disciplines
- Standardize the Process used to Evaluate and Select Space Investigations
- Optimize the Use of Existing Space Hardware and Special Ground Facilities Among International Community
- Coordinate the Planning and Development of New Space Hardware or Special Ground Facilities

Goal 2: Enhance Knowledge and Information Exchange

STRATEGY

- Encourage the Development of Agency Management Policies that Assure the Exchange of Scientific Information
- Inform the Scientific Community of the Results of Space Missions
- Encourage the Development of Partnerships Between Space Agencies and Traditional Science Funding Agencies Within Each Country
- Support the Preservation of Space Flight Data
- Provide the International Scientific Community with Access to Space Flight Data
- Encourage the International Exchange of Graduate and Postgraduate Students
- Support the Development of Educational Materials Related to the Space Life Sciences
- Develop an International Report on the Benefits of Space Life Sciences Research

B. Implications of Implementing the Strategic Plan

The implementation of an International Space Life Sciences Strategic Plan will provide increased efficiency and opportunities for all participating life sciences programs. Leading international scientists will provide collective and ongoing reviews published for general circulation of the current state of research in specific areas of space life sciences, allowing individual agencies to make independent but educated management decisions. Flight opportunities will be more effectively used through international recruitment of science teams and internationally coordinated planning for short duration missions as well as for the challenge of research on a space station. Scientists will be able to more carefully plan experiments and more fully analyze the data from previous flight experiments through compatible and universally available archives of flight data.

These benefits and the potential increase in effectiveness require active participation by member agencies. International coordination will need to be considered at every stage of the scientific process. Active support of scientific planning and, in particular, expert panels and international peer review, by each agency will be necessary. This action will also require a commitment to international cooperation during program planning. It may be necessary, for instance, to alter review and planning schedules to coordinate with an international schedule. Such a plan could also allow an agency to defer hardware construction in one specific area through the sharing of internationally pooled facilities, while, at the same time, concentrating hardware development resources in another area. Effective use of space flight data by the international community will require the archiving of data in a compatible format and with reasonable promptness.

These implications do not, in general, lead to cost increase in programs, but rather to a commitment to the concept that international cooperation, to the degree acceptable to each agency, will provide greater scientific and technical return for a minimum of change in activities at the program level.

VI. APPENDICES

Appendix A. Process Utilized to Develop the Strategic Plan

Throughout the 1980s, the space agencies of Canada, the Federal Republic of Germany, France, Japan, and the United States, and the European Space Agency each pursued cooperative projects in the space life sciences through bilateral and multilateral agreements. By 1989, the growth of these life sciences programs reflected increased levels of maturity, ambition and complexity that argued for collective action to enable the future to develop in a strong, mutually beneficial way. Thus, preliminary and informal discussions among the agencies' senior life sciences officials led to a workshop hosted by the European Space Agency in Frascati, Italy in April 1989 to consider this question: Can a unified approach be developed for space life sciences that would encompass the scientific and operational goals of the agencies, and that would extend to all space platforms and to current and future research activities on them? The workshop came up with a positive response and recommended the formation of the International Space Life Sciences Strategic Planning Working Group to develop and carry out the approach.

The first official meeting of the working group took place in Montreal, Canada in October 1991. It formally adopted its Charter (see Appendix B), and began to function. The strategic plan that the working group was chartered to develop was drafted in outline form in 1991 and has been revised several times. The final plan was released for agency review in 1994 and formally adopted in June 1995.

Appendix B. Charter for the Working Group

INTERNATIONAL SPACE LIFE SCIENCES STRATEGIC PLANNING WORKING GROUP

Charter

15 March 1990

1.0 Purpose

The purpose of this Charter is to establish the International Space Life Sciences Strategic Planning Working Group (hereinafter called the Working Group) to develop and periodically update an International Strategic Plan for the Space Life Sciences (hereinafter called the Strategic Plan).

2.0 Scope

This Charter is applicable to those agencies which agree to participate in this Working Group and contribute to the development of the Strategic Plan, and seek the implementation of the cooperative programs defined in this plan. This Charter is limited to those programs agreed upon and described in the Strategic Plan, and does not supersede any existing bilateral or multilateral agreements and/or ongoing projects of any participating agency.

3.0 Background

During the 1980's, each of the Charter agencies with an interest in and commitment to the space life sciences has pursued vigorous international cooperative programs and projects on a bilateral or multilateral basis. By 1989, the various space life sciences programs within these agencies have reached a level of maturity which justifies coordinated strategic planning to cope effectively with future multilateral research programs and implementation issues.

4.0 Working Group Membership

Each Charter agency participating in this Working Group will designate up to two representatives to serve on this Working Group. The Charter agencies as of the effective date of this Charter are the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and the space agencies of Canada, France, Japan, and the Federal Republic of Germany. Upon request, other governmental agencies with programs in the space life sciences will be considered for membership in this Working Group, as appropriate. Decisions regarding membership will be made by vote of the Working Group, with majority rule.

5.0 Working Group Chairpersons and Executive Secretary

The Working Group will have two co-chairpersons selected annually from among the representatives on the Working Group. One co-chairperson will be from NASA. An Executive Secretary will be chosen annually by the Working Group. The Co-chairpersons are responsible for developing the agenda for each Working Group meeting, with the assistance of the Executive Secretary. The Executive Secretary is responsible for the preparation and distribution of the minutes of each meeting, and is supported in this activity by the agency hosting the meeting.

6.0 Meetings

Meetings of the Working Group will be held at least once a year, and as determined by the Co-chairpersons. Meetings will be hosted on a rotating basis by each participating agency.

7.0 Minutes

Minutes will be prepared by the Executive Secretary and distributed to the Working Group members and to each participating agency's international affairs office, or its equivalent, no later than 45 days following each meeting. Each participating agency is responsible for assuring that the minutes are reviewed by the appropriate agency personnel, and for assuring that additions, deletions, and corrections are returned to the Executive Secretary within 30 days of the receipt of the minutes. Final approval of the minutes by the Co-chairpersons will take place no later than 90 days following each meeting.

8.0 Strategic Plan

The resultant Strategic Plan will contain a common set of goals and objectives derived from the current plans of each of the participating agencies. This plan will include both current and future activities in the space life sciences and will provide a framework that facilitates the identification of opportunities for coordination and cooperation utilizing the full range of space carriers and platforms.

9.0 Other Activities

The Working Group may coordinate, by consensus of all participating agencies, other multilateral activities related to the Strategic Plan. These activities may require the formation of implementation teams with a membership determined by the agencies actually involved in the specific programs or projects requiring multilateral coordination.

10.0 Agency Coordination

The members of the Working Group are responsible for making certain that appropriate senior management personnel and relevant advisory committees, if any, from their agency are fully aware of the activities of the Working Group. Each participating agency is responsible for securing the necessary approvals for all such activities according to the rules and procedures of that agency.

11.0 Expenses

Each agency will bear the costs of discharging its respective responsibilities related to the activities of this Working Group without transfer of funds, including travel and subsistence of its own personnel as required to attend meetings.

12.0 Duration and Amendment of Charter

This Charter will become effective with the signature of at least four of the Charter agencies listed in Section 4.0 above, and can be amended by consensus of the Working Group members. This Charter will continue in effect for five (5) years from this effective date. After this period, a new Charter may be negotiated for the continued existence of this Working Group.

13.0 Termination of Participation

Individual member participation in this Working Group may be terminated by any of the agencies, with 90 days prior notification to the co-chairpersons.

Appendix C. Agency/Program Descriptions

Canadian Space Agency (CSA)

The Canadian Space Agency (CSA) was established in 1989 with the mandate to promote the peaceful use and development of space for the social and economic benefit of Canadians. However, Canada's experience in space began in 1962 with the launching of the Alouette 1 research satellite. Canada was the third country in the world after Russia and the United States to design and build its own satellite. With the launching of Anik 1, Canada became the first country in the world to have a commercial geostationary communication satellite network. CSA currently participates at an international level as an associate member of the European Space Agency as well as a member of the International Space Station Program. The CSA has headquarters in the Montreal Metropolitan area with the Science Division and the Space Testing Facilities (David Florida Lab) located in Ottawa.

Formal organization of Space Life Sciences in Canada started in 1984 after many years of contributions by individual scientists. Canadian astronaut flights provided opportunities to further life science research opportunities and provide a focus for the life science flight experiments.

The Space Life Sciences program currently supports more than 15 flight experiments and 30 investigator teams. Funding for the ground-based activities takes place in cooperation with national academic funding agencies. The program has identified five areas of priority for research over the next five years:

- Muscle and Bone Loss,
- Cardiovascular and Fluid Regulation,
- Early Development,
- Neurophysiology, and
- Radiation.

The program is also actively involved in the planning and preparation for the scientific utilization of the International Space Station.

Centre National d'Études Spatiales (CNES)

CNES, the French Space Agency, was created in December 1961, and was commissioned by the government to outline the broad objectives of French space policy, to develop the necessary scientific and technical tools, and to ensure their coherence.

CNES is acting in a national, European and international arena. CNES activities are spread over five locations: Paris (Headquarters), Evry (rocket related activities), Toulouse (technical center), Kourou (launch site), and Aire sur l'Adour (stratospheric balloon activities). Due to the growth of space activities, CNES has turned to the founding of commercialization companies, whenever space technology has led to new products and services (launch services, remote sensing).

France implements a coherent and balanced program which features six major goals:

- guarantee autonomous access to space for France and Europe;
- reinforce the main applications of space (telecommunications and earth observation);
- coordinate civilian and military developments for space utilization;
- develop the technologies needed for future space activities;
- promote space research in the field of space sciences (astronomy, solar exploration);
- participation in programs of orbital infrastructures, and, more generally, in programs of in-orbit experiments in domains like biology, space physiology and medicine, fluid physics, materials sciences, and fundamental physics.

In the domain of Life Sciences, the program began in 1970. Since this period, an important program of in-orbit experimentation has been implemented through bilateral cooperation with the US and Russia or through ESA. More than 50 science teams are supported by CNES for ground preparatory programs, suborbital experiments, and for inflight experiments. The main fields of investigation are the following:

- neurosciences: sensorimotricity, cognition, and development;
- cardiovascular physiology: blood pressure and heart rate regulation;
- musculoskeletal physiology: atrophy and osteoporosis;
- gravitational biology, radiobiology, and dosimetry; and
- exobiology.

The flights of French astronauts have greatly contributed and will still contribute in the future to the successful accomplishments of the scientific programs. CNES has initiated a national Institute for Space Medicine in Toulouse, called MEDES, which is a logistic support for CNES.

Deutsche Agentur für Raumfahrtangelegenheiten (DARA)

The German Space Agency DARA (Deutsche Agentur für Raumfahrtangelegenheiten) was established in the summer of 1989 as the central management organization to coordinate all space activities of the Federal Republic of Germany. DARA's responsibilities include:

• To draw up plans for German space policy for approval by the Federal Government

  - Planning German participation in international programs and projects
  - Planning national projects with due consideration for European, bilateral, and multilateral programs
  - Technological, economic, and financial recommendations, analyses, and project

proposals

- To implement German space programs and award industrial contracts and grants

    - Advising and assisting the Federal Ministries and public institutions involved, as well as coordinating activities with industry and scientific institutions

    - Promoting, directing, and monitoring projects and evaluating their results

    - Planning and coordination of operating facilities

    - Initiatives to promote commercialization

    - Allocating funds from the space budget in accordance with its statutory authority, and determining financial requirements

- To represent German space interests in the international arena, particularly within ESA

    - Representing the German position on the committees of ESA and other international organizations

    - Participating in drawing up and controlling ESA programmes

    - Representing the German position in the implementation of multilateral and bilateral agreements

A close partner of DARA is the German Aerospace Research Establishment (DLR), which is directly funded by the German government and performs its space-related research in mutual agreement with DARA within the frame of the German space program. DLR can also be responsible for different operational aspects of space projects via contracts from DARA and ESA.

Life Sciences research in Germany started in 1972 with experiments in radiation biology. Since then, important achievements have been obtained in attempts to reach the major program goals, which have recently been redefined in accordance with scientific advisory groups:

- To achieve fundamental scientific insight into the response of biological systems to space conditions;

- To contribute to terrestrial basic and application-oriented research by improvements of existing technologies as well as by the development of novel methods and materials;

- To contribute to the global exploration of the ecosystem Earth;

- To acquire the medical and technological fundamentals for the stay of humans in space; and

- To strengthen the German position and competence in important areas of research under space conditions.

More than 50 scientific groups are presently funded by DARA for space life sciences research in the following areas: Gravitational Biology, Radiation and Exobiology, Bioregenerative Life Support/Artificial Ecosystems, Bioprocessing, and the broad field of Human Physiology with emphasis on studies of the cardiovascular, the vestibular, and the musculoskeletal systems, of endocrinology and metabolism as well as of operational medicine aspects.

In order to achieve the ambitious program goals, most activities are embedded in the framework of close international cooperation. Besides the European Space Agency (ESA), DARA's bilateral and multilateral partners include, above all, the USA, but also Russia, France, Canada, Japan, and China.

European Space Agency (ESA)

The European Space Agency, ESA, is an international organization whose task is "to provide for and to promote, for exclusively peaceful purposes, cooperation among European states in space research and technology and their space applications." ESA has 14 Member States: Austria, Belgium, Finland, France, Denmark, Germany, Italy, Ireland, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. Canada takes part in some projects under a cooperative agreement.

The Agency was born in 1975 from the merging of two organizations that had already been involved in the European space effort since the early '60s: ESRO (the European Space Research Organization) in charge of developing satellites, and ELDO (the European Launcher Development Organization) involved in developing and building a European launcher. ESA is to Europe what NASA is to the USA. It draws up a European space plan and has the task of carrying it out. ESA's involvement spans the fields of space science, Earth observation, telecommunications, space segment technologies including orbital stations and platforms, ground infrastructures and space transportation systems, as well as basic research in microgravity (the technical term for "almost complete absence of gravity").

ESA has its headquarters in Paris, France. This is where ESA's Director General has his office and where the Agency's governing body, the Council, meets. The Council is made up of government representatives from the various Member States and is supported by a number of committees dealing with the science program, industrial policy, international relations and administrative and financial matters. The various program directorates are also housed at ESA Headquarters, together with the administrative services. Headquarters has a staff of approximately 350.

The Agency has a number of establishments (ESTEC, ESOC, ESRIN and EAC), a launch base at Kourou in French Guiana, a liaison office in Washington, DC, an office in Brussels for relations with the European Community, and a liaison office in Moscow for common projects with Russia.

Microgravity research first appeared in the 1970's when both Americans and Soviets carried out experiments during some of their manned space flights. The interest of European scientists in the new research field was stimulated when Europe decided to develop Spacelab as a European contribution to the U. S. Space Shuttle program. During the late 1970's several multi-user experiment facilities such as furnaces, growth chambers and a vestibular research facility (Sled) were developed in Europe, specifically for use in Spacelab on its first flight.

ESA's Microgravity Research Program covers a wide range of fields such as solidification physics (e.g., crystal growth, metallurgy), physical chemistry, and fluid sciences. It also includes the life sciences, whose span includes biology, biotechnology, human physiology, and medicine. The Agency's Microgravity Program formally started on 15 January 1982, when Member States agreed that such a program, of which the initial step (Phase 1) lasting four years was to be carried out as an optional program. The Phase 1 included several basic elements, one of which was dedicated to the life sciences: development and flight of Biorack, a multipurpose facility for cell biology, on the Spacelab mission D-1.

In 1985, Phase 2 of the Microgravity Program, covering the period 1985-88 was approved and 11 Member States participated in this program. The Challenger disaster in January 1986 resulted in a serious discontinuity, of six years' duration, of Spacelab flight opportunities with European participation. This accident led to delays in payload development and to a partial reorientation of the program. More emphasis was given to Sounding Rockets and a cooperation in biological payloads (Biokosmos flights) was established in 1987 with the former Soviet Union. Therefore, in 1988 the First Extension of Phase 2 was approved; it lasted until January 1992 at which time Spacelab flights with European participation (IML-1) were resumed.

Up to now, the most important flight opportunities for microgravity research experiments were provided by Spacelab missions. Today, after five Spacelab missions with ESA participation, there are several hundreds of scientists and engineers in Europe who are working on various aspects of research exploiting the microgravity environment in space in the context of ESA's Microgravity Program. The five Spacelab missions just mentioned were the first Spacelab mission, SL-1, carried out as a joint ESA/NASA mission in late 1983, the German Spacelab missions, D-1 and D-2, with a strong ESA participation flown in October/November 1985 and April 1993 respectively, and the International Microgravity Laboratory missions, IML-1 and IML-2, both with a major ESA participation and flown in January 1992 and July 1993 respectively.

In addition, about 200 short duration experiments were carried out with sounding rockets (typically seven minutes of microgravity duration). Also, carriers of the former Soviet Union, mainly the unmanned retrievable spacecraft called Biokosmos or Foton, were used in the aftermath of the Challenger accident in ESA's Microgravity Program. Other experimental opportunities are provided by drop towers (a few seconds) and aircraft flying parabolic trajectories (approximately 20 seconds). In addition, the EURECA mission in 1992/93 provided a very useful opportunity for long duration experiments.

In 1992, the Microgravity Program Board adopted a resolution on the future structure of the Microgravity Program, which was approved by the Council at Ministerial level. The Resolution stated that in future the Agency's Microgravity activities should be split into two distinct financially independent elements:

- A basic European Microgravity Research Program (EMIR) for covering basic research activities and ensuring a continuation of the microgravity experimentation possibilities to the user community on a long-term basis.

- A program to develop the facilities required for microgravity experiments to be carried out in the Columbus Attached Laboratory (MFC = Microgravity Facilities for Columbus).

The motivation for this separation of basic research activities from major hardware developments for large infrastructure elements was the desire of delegations to ensure a modest, but assured, funding for research activities, independent of possible programmatic changes and delays in the infrastructure programs.

The Agency solicits experiment proposals with Announcements of Opportunity which are followed by science and technical peer reviews that make recommendations about flying experiments in space. Final selection rests with the responsible Microgravity Program Board. The necessary guidance and advice in scientific matters rest with the Life Sciences Working Group, composed of outside ESA scientists and experts in the relevant fields of research.

National Aeronautics and Space Administration (NASA)

The National Aeronautics and Space Administration came into existence October 1, 1958, established by an Act of Congress July 16, 1958. The immediate cause for the creation of a civilian space agency was the Soviet Union' launch of Sputnik 1, the world's first artificial satellite. NASA was formed from the National Advisory Committee for Aeronautics (NACA), the Vanguard Division of the Naval Research Laboratory, the Jet Propulsion Laboratory, the Development Operations Division of the Army Ballistic Missile Agency, and the Missile Firing Laboratory to lead the nation in civil aeronautics and space. NASA has taken us to the edge of the solar system and beyond, exploring every planet, to include Earth and its moon, with the exception of Pluto, using the Surveyor, Ranger, Lunar Orbiter, Pioneer, Viking, and Voyager scientific spacecraft. Earth satellites have allowed for worldwide communication and improved weather prediction, crop inventories, and oceanic, geological, and urban development studies.

The first decade of NASA's space activity was dominated by the challenge issued by President John F. Kennedy in May 1961, to place a man on the moon and return him safely to Earth by the end of the decade. On July 20, 1969, Apollo 11 astronaut Neil Armstrong became the first human to step on the Moon. This achievement built upon the preceding Mercury and Gemini projects which demonstrated a human tolerance for space flight and the capability to build the launch vehicles and spacecraft necessary for such a complex mission. The last Apollo mission in December 1972 was followed by three Skylab missions (1973-74) which adapted Apollo hardware into an "orbiting workshop" to study the effects of long-duration space flight on humans and to make astrophysical observations, particularly of the sun. In July 1975, Americans joined hands with Soviet cosmonauts during the first large-scale international cooperative human space flight, the Apollo-Soyuz Test Project (ASTP), but six years lapsed before another human flight. First flown in 1981, the space shuttle was designed to provide routine access to space (as well as to the international space station) by incorporating the qualities of winged aircraft with rocket propelled spacecraft to form a reusable system. The space shuttle deployed a variety of satellites and space probes during the first 24 missions that preceded the Challenger accident of January 28, 1986. Though never able to attain its originally planned flight rate, the shuttle was redesigned and returned to flight in October 1988 and has flown nearly 70 successful missions through the end of 1994.

NASA's programs in the space life sciences are managed by several different Offices and Division. All of these programs are focused on ensuring the health, safety, and productivity of humans in space, or on acquiring fundamental scientific knowledge in the space life sciences, or on both. The major goals of the space life sciences within NASA are to:

- Effectively use microgravity and the other characteristics of the space environment to enhance our understanding of fundamental biological processes;
- Understand the origin, evolution, and distribution of life in the universe;
- Provide operational medical support to all space missions involving humans;
- Develop the scientific and technological foundations for a safe, productive human presence in space for extended periods and in preparation for exploration; and
- Apply this knowledge and technology to improve our nation's competitiveness, education, and the quality of life on Earth.

NASA operates nine Field Centers from its Headquarters in Washington, DC. These include: Ames Research Center, Moffett Field, CA; Dryden Flight Research Center, Edwards, CA; Goddard Space Flight Center, Greenbelt, MD; Jet Propulsion Laboratory, Pasadena, CA; Lyndon B. Johnson Space Center, Houston, TX; John F. Kennedy Space Center, Kennedy Space Center, FL; Langley Research Center, Hampton, VA; Lewis Research Center, Cleveland, OH; Marshall Space Flight Center, Huntsville, AL; John C. Stennis Space Center, Stennis Space Center, MS.

National Space Development Agency (NASDA)

Japan's Space Program is planned and supervised by the Space Activities Commission, an advisory committee to the Prime Minister. It is mainly organized into two subprograms of activities, with NASDA covering developments and practical space applications and with the Institute of Space and Astronautical Science (ISAS) covering the field of space sciences.

NASDA was established on October 1, 1969 as the central implementation organization for the Law Concerning the National Space Development Agency of Japan (June 23, 1969, Law no.50). In this role it contributes to the advancement of space exploration and the utilization of practical applications on earth for peaceful purposes. Based on a Space Development Basic plan formulated by the Prime Minister, NASDA carries out the following activities:

- Development of satellites and launch vehicles for satellite launching, as well as launch and tracking technology and space utilization technology (including space experiment and space station development);
- Development of the methods and facilities required for these activities including those required for space experiments and space stations.

Use of the space environment takes advantage of the special conditions of outer space such as microgravity, vacuum, and infinite space, to develop the new materials that will support the basic life in the 21st century while contributing to development of life sciences, engineering, astronomy and earth observation. These activities herald a new generation in space development. Not only can these activities create new scientific technology, knowledge and technology gained through use of the space environment can be applied on earth to promote socioeconomic development. The knowledge and technology amassed through use of the space environment holds the possibility of space development activities going beyond the sphere of the Earth.

As a part of the activities to promote use of the space environment, NASDA has been planning and facilitating the space experiment projects using sounding rockets, US Space Shuttle, and Spacelab systems. Japan also joins the US, the European Space Agency (ESA), Canada, and Russia in the Space Station Program to be completed in the next century and is providing the Japanese Experiment Module (JEM) which will be an attachment to the Space Station Alpha. This program is being undertaken at the Tsukuba Space Center where a Space Station Integrated Project (SSIP) Center has been established to promote development, operation and testing of JEM elements while training astronauts.

NASDA is currently facilitating these activities to support the wide area of space development and its utilization:

Expanding humanity's intellectual frontiers by space exploration.

Scientific exploration of the uncharted reaches of space is an effort to answer our most fundamental questions about the origin and future of the universe, the solar system, the Earth and life. Space exploration, an attempt to widen our intellectual frontiers, is thus becoming increasingly important. The diverse kinds of knowledge and information gained in this way produce new views of the universe, the earth and of life itself.

Protecting the global environment.

In dealing with problems of global dimensions such as the protection of the global environment, it will be crucial to employ global observation systems to carry out regular and precise observations of changes in the atmosphere, oceans and of the earth's surface. Observation targets include changes caused by global warming, reduction in greenery, desertification, damage to the ozone layer, natural disasters, and the dispersal of natural resources. In the long term, by enlarging our living space to include the universe, we will find that space can provide us with natural resources and energy as Earth-based supplies dwindle. We expect to make efficient use of these resources in space.

Realizing a bountiful life and a vital society.

Many forms of technology have become indispensable in our daily lives. They include weather reports from weather satellites, television broadcasts utilizing broadcasting satellites, and automobiles using Global Positioning Systems. Use of such satellite systems are now become increasingly sophisticated on a global level. Functioning as important systems that support our high level information content, NASDA will make a major contribution to realizing a more pleasant and convenient life, both spiritually and materially.

Development of leading edge space technology for future creation.

Developmental technology for use in space must be suited to the severe environments found there, such as high vacuum, and at the same time offer high reliability and safety. Space technology, a trail blazing blend of technologies affects not only all aspects of human society, but also materials and information. Untiring efforts to develop, improve and perfect space technology will give birth to new technologies in many fields including materials, computers, electronics, robotics, communications, information processing and life sciences.

Achievement of international society.

In the field of earth observation there have been joint efforts in utilizing satellites to observe the entire global environment. The United States, Europe, Japan, Canada and Russia are now engaged in joint development of a space station scheduled to start operating early in the next century. This demonstrates that large scale space project tend to materialize through mutual cooperation which transcends national boundaries.

Nurturing human resources for the next generation.

Ambitious dreams and a spirit of accepting challenges instill today's youth with a vigor that creates sound minds and bodies. For our youth, space is a great dream and one of the future's challenging goals. By passing on the dream of space exploration to the younger generation we can promote the development of future human resources who will be active in a whole host of fields not limited to science and technology.

Appendix D. International Activity in the Space Life Sciences Disciplines

RELATIVE EMPHASIS IN LIFE SCIENCES RESEARCH AREAS (0 = No Activity, 1 = Minor, 2 = Nominal, 3 = Major Activity; + = increasing, - = decreasing) RESEARCH AREA CNES CSA DARA ESA NASA NASDA Biological Materials Science 2- 1 2- 2 2 2 Molecular and Cellular Biology 2 2 2+ 3 2+ 2+ Developmental and Reproductive Biology 2+ 3 1 2+ 1+ 1 Plant Biology 1+ 0+ 3 2 2+ 1 Cardiopulmonary Physiology 3 3 3- 3- 2- 2 Musculoskeletal Physiology 2 2+ 1+ 2+ 2+ 2 Neurosciences 3 3- 3 2 3 3 Regulatory Physiology 3 3 2 2+ 2 1 Behavior, Performance, and Human Factors 2- 1+ 1 1 1+ 1+ Medical Support Systems 2- 1 0 0 3 1+ Life Support Systems 1 0+ 2+ 1 2 1+ Environmental Health 1 0 1 1 2 1 Radiation Health 2+ 3 2 1 1+ 2+ Exobiology 1+ 0 1 1+ 3 1 Biospherics Research 0 0 1 0 2 1+

Definitions of Research Areas

Biological Materials Science

Concerns space research related to both macromolecular crystal growth and separation processes related to biological materials.

Molecular and Cellular Biology

Examines how gravity and other space flight factors influence biological function at the molecular and cellular level, including the identification of how single cells "sense" gravity, how this information is translated into biological responses, and how cells respond to both acute and long-term variations in gravity and other flight factors.

Developmental and Reproductive Biology

Focuses on the influence of gravity and other flight factors on reproduction, genetic integrity, differentiation, growth, development, life span, senescence, and subsequent generations of animals.

Plant Biology

Concerns the effects of gravity and other flight factors on the growth, development, reproduction, movement, and orientation of plants and on the underlying mechanisms responsible for these effects.

Cardiopulmonary Physiology

Examines acute and long-term cardiovascular and pulmonary adaptation to space flight and subsequent readaptation to the normal environment of Earth, including all associated underlying mechanisms of action.

Musculoskeletal Physiology

Focuses on the responses and consequences of muscle and skeletal adaptation to space flight and subsequent readaptation to the normal environment of Earth, including all associated underlying mechanisms of action.

Neurosciences

Concerns the acute and long-term adaptation of the central and peripheral nervous system to space flight and the subsequent readaptation to the normal environment of Earth, including all associated underlying mechanisms of action.

Regulatory Physiology

Examines the following areas of acute and long-term adaptation of animals to space flight and subsequent readaptation to the normal environment of Earth: circadian rhythms, endocrinology, fluid and electrolyte regulation, hematology, immunology, metabolism and nutrition, and temperature regulation.

Behavior, Performance, and Human Factors

Examines the basic mechanisms underlying the behavioral adaptation to space flight, the measurement and interpretation of performance during space flight, and the factors that influence the capabilities and limitations of crewmembers on space missions of varying duration.

Medical Support Systems

Focuses on the goal of providing preventive, diagnostic, and therapeutic capabilities for space flight operations and includes both countermeasure development and clinical studies.

Life Support Systems

Concerns the integration of biological, physical, and chemical processes to promote self-sufficiency in life support by improving the regeneration of air, water, and food, by managing and recycling metabolic and other wastes to achieve optimum resource recovery and use.

Environmental Health

Examines the effects of the spacecraft environment on humans and other organisms in order to manage those environments properly to minimize risks associated with living and working in space; includes the areas of barophysiology, microbiology, toxicology, and environmental monitoring.

Radiation Health

Focuses on developing the scientific basis for the radiation protection of humans engaged in the exploration of space, with a particular emphasis on the establishment of a firm knowledge base to support risk assessment for future long-term exploration missions.

Exobiology

Concerns research related to those processes involved in the origin, evolution, and distribution of life in the universe.

Biospherics Research

Examines ways to measure and predict biological changes on Earth on a regional and global scale and to assess the biological consequences of those changes.

Appendix E. Definition of Thematic Areas

The thematic areas defined here and discussed in Section IV.C represent only one way of representing the normal set of space agency activities required in the overall management of space research. They are chosen for convenience only.

Management and Policy - This theme is concerned with those activities directly related to the formal mechanisms and conduct that the various space agencies follow to foster cooperation and collaboration, facilitate communication, and identify and evaluate opportunities for international cooperation.

Discipline Review and Planning - This theme is concerned with the periodic scientific review and assessment of accomplishments within a particular scientific discipline, with the development of the list of critical questions facing that discipline, and with the determination of the relative importance of these questions.

Flight and Ground Facility Development and Sharing - This theme is concerned with the actual space hardware or ground facility definition and development process and with the bartering process used to achieve balance through sharing and cooperation.

Science Recruitment, Review, and Selection - This theme is concerned with the various elements of the investigator solicitation process, the conduct of scientific peer review and engineering feasibility review of studies, and with the selection process used to obtain individual and team investigations.

Data Archiving, Distribution, and Utilization - This theme is concerned with the archiving of space flight data and bibliographic information and with the distribution of that data and the support of the utilization of that data by the scientific community.

Investigator Community Development - This theme is concerned with activities related to expanding the scientific community involved, or interested in being involved, with ground or flight research in the space life sciences.

Educational Activities - This theme is concerned with those activities focused on education and training of young people in the space life sciences, on the use of the motivating power of space life sciences research to improve the way science is taught generally, and on the education of members of the scientific community as to the importance of space life sciences research.

Earth Benefits - This theme is concerned with fostering a clear picture of the variety of benefits accruing to people on Earth today as a result of past and future ground and space research in the space life sciences.